

REMARKS

The application has been amended to form and is believed to be in condition for allowance.

Applicants acknowledge with appreciation that the amendments of the Amendment dated November 9, 2007 have been entered into the application.

Applicants also thankfully acknowledge the indication that claims 28-29 recite patentable subject matter and would be allowable if rewritten in independent form.

Claims 1-8, 20, 21 and 27-29 remain in this application.

Claims 2 and 27 have been non-substantively amended as to form without introducing new matter. Entry of the amendments is earnestly solicited.

The Official Action rejected claims 1-8, 20-21, and 27 under 35 USC 103(a) over HAASE (US 2003/0211724 A1; hereinafter HAASE) in view of DUBIN et al. (US 5,913,147; hereinafter DUBIN).

The claim rejections are respectfully traversed by at least the reasons that follow.

With respect to claim 1, the Official Action states that HAASE discloses a semiconductor device comprising a connection plug defined by a via hole filled with a conductive barrier material comprising a nanomaterial surrounded by the conductive barrier material, wherein the conductive material

both surrounds the nanomaterial and fills the via hole. The Official Action makes reference to paragraphs [0021-0022] of HAASE in support of the rejection.

The Official Action concedes that HAASE does not disclose the conductive material is metal, as required in claim 1.

The Official Action states that DUBIN teaches that it is well known for a metal to be used as a barrier material between a copper wire and a dielectric layer. The Official Action concludes that it would have been obvious to one of skill in the art at the time the invention was made for the conductive barrier material of HAASE to be a metal, such as taught by DUBIN, in order to improve the adhesion of copper layer 34a of HAASE to dielectric layer 26. The Official Action cites DUBIN, column 1, lines 31-39, in support of the conclusion.

In response, it is respectfully submitted that neither HAASE nor DUBIN, individually or in combination, teaches or suggests a connection plug defined by a via hole filled with a metal comprising a nanomaterial surrounded by the metal, wherein the nanomaterial is substantially uniformly disposed in a section of the via hole, and the metal both surrounds the nanomaterial and fills the via hole, as recited by claim 1.

As illustrated in Figures 1-8, the invention comprises an interconnection formed from a mixed material of a nanomaterial 14 and a metal 39, wherein the elongated surface of the nanomaterial 14 is encased in the metal 39. In the case where the nanomaterial is a carbon nanotube, this structure of materials reduces the contact resistance of the interconnection (see specification page 9, lines 2-8). Fibrous nanotube materials in this arrangement, such as thin silicon wire, increase the strength of the metal forming an interconnection that is resistant to vibration, mechanical and thermal stress (page 8, lines 9-17).

In contrast, HAASE teaches a via hole comprised entirely of nanotubes densely packed together. Figure 3 clearly illustrates a cluster of nanotubes, seen from the top of a via, packed together such that the surfaces of each nanotube are in contact with at least one other nanotube (see paragraph [0020]). HAASE teaches a particular embodiment wherein a via is filled with hexagonally packed, multi-walled carbon nanotubes (paragraph [0023], emphasis added). HAASE does not teach or suggest a via hole filled with a metal comprising a nanomaterial surrounded by the metal, as required by claim 1.

The Official Action states that HAASE discloses a conductive barrier material 34b filling a via hole. Respectfully, this is not believed to be true. As illustrated

in Figures 1 and 2, barrier material 34b may be deposited so that it surrounds second ends 48 of carbon nanotubes 32, "possibly extending into via 24 so as to substantially surround second ends 48 even of any carbon nanotubes whose second ends 48 do not extend outside of via 24," (paragraph [0021], emphasis added). The extent of the penetration of barrier material 34b is illustrated in Figures 1 and 2 by a horizontal line cutting across via 24 near the top of via 24 running between dielectric 26, dividing second ends 48 from first ends 44.

Neither HAASE nor DUBIN teaches or suggests that barrier material 34b extends to surround or even make contact with the first ends 44 of the carbon nanotubes 32 extending from the bottom of the via 24 (Figures 1-2). On the contrary, HAASE teaches a via 24 filled with hexagonally packed, multi-walled carbon nanotubes, as stated above (paragraph [0023]; Figures 1-2). There is no teaching or suggestion, either in HAASE or DUBIN, individually or in combination, of via 24 being filled with anything else.

Furthermore, HAASE teaches barrier material 34b as a layer protecting the upper part of the carbon nanotubes 48 and via 24 from inversion by conductive layer 34 (Figures 1-2); thus, there is neither teaching nor motivation to fill via hole 24 with metal as required by claim 1. Therefore, HAASE and DUBIN, individually or in combination, make no teaching or

suggestion that barrier material 34b i) comprises a nanomaterial surrounded by the metal and ii) both surrounds the nanomaterial and fills the via hole 24, as required by claim 1.

Accordingly, HAASE and DUBIN, individually or in combination, fail to satisfy the recitations of claim 1. Therefore, it is respectfully submitted that claim 1 and claims depending therefrom are patentable. Reconsideration and withdrawal of the rejection are respectfully requested.

It is respectfully submitted that claim 2 is patentable by the same reasoning set forth above pertaining to claim 1. Neither HAASE nor DUBIN, individually or in combination, teaches or suggests an interconnection comprising a metal layer filling a trench and nanotubes mixed in the metal layer as required by claim 2. Accordingly, it is respectfully submitted that claim 2, and claims depending therefrom, are patentable. Reconsideration and withdrawal of the rejection are respectfully requested.

It is respectfully submitted that claim 27 is patentable by the same reasoning set forth above pertaining to claims 1 and 2.

Additionally, neither HAASE nor DUBIN, individually or in combination, teaches or suggests a metal layer filling a trench and a barrier metal layer coating a bottom and sides of the trench, where the barrier metal layer is located

intermediate the metal layer and the dielectric film with the barrier metal layer separating the metal layer from the dielectric film, particles of metal on a lower horizontal surface of the barrier metal layer, and carbon nanotubes formed on the metal particles and mixed in the metal layer, as recited by claim 27.

Neither HAASE nor DUBIN teaches or suggests two metallic layers, a metal layer and a barrier metal layer, where the metal layer fills the trench and the barrier metal layer coats a bottom a sides of the trench, and the barrier metal layer is between the metal layer and the dielectric film (see Figures 4a-4g and 5).

As stated above with respect to claims 1 and 2, the barrier layer 34b of HAASE does not fill the trench with carbon nanotubes mixed in it. Thus, barrier layer 34b does not satisfy the recitation of the metal layer of claim 27.

HAASE also does not teach particles of metal on a lower horizontal surface of barrier layer 34b. In contrast, HAASE teaches metal particles on a tungsten surface 30 which does not coat the sides of the trench (Figure 2). This tungsten surface neither fills the trench nor coats the walls of the trench.

Further, where HAASE teaches a barrier layer incidentally forming along the walls of the trench, the barrier layer is silicon carbide (paragraph [0022]) which is

not a metal as required by claim 27, and HAASE makes no teaching of this incidental barrier layer coating the bottom of the trench in addition to the sides.

Thus, none of HAASE's barrier layer 34b, tungsten surface 30, or HAASE's incidental barrier layer (paragraph [0022]) satisfies the recitation of a barrier metal layer, with particles of metal on its lower horizontal surface, coating the sides of the trench, and intermediate the metal layer that fills the trench, as required by claim 27.

Therefore, it is respectfully submitted that neither HAASE nor DUBIN, individually or in combination, teaches or suggests all the recitations of claim 27. Accordingly, it is respectfully submitted that claim 27, and claims depending therefrom, are patentable. Reconsideration and withdrawal of the rejection are respectfully requested.

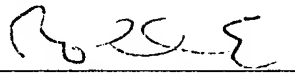
From the foregoing, it will be apparent that applicants have fully responded to the December 6, 2007 Official Action and that the claims as presented are patentable. In view of this, applicants respectfully request reconsideration of the rejected claims, as presented, and their early passage to issue.

Should there be any matters that need to be resolved in the present application, the Examiner is respectfully requested to contact the undersigned at the telephone number listed below.

The Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 25-0120 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17.

Respectfully submitted,

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